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SOME PROBLEMS FOR AGRICULTURAL CHEMISTS.[1]

THE topic of my paper is not intended to convey the idea that I have anything new or startling to suggest, or that I intend to point out the shortcomings of the American agricultural chemist. My purpose is mainly to state what an experience of twenty-five years has suggested in the way of chemical investigations that seem now to be essential, if we are to maintain, or increase, the fertility of our soils, and thus retain the position that we have acquired as an agricultural people. We have in this country quite as capable chemists, I am sure, as there are in any country, yet the conditions existing here in the past, and that do exist now, in a way, have been such as to demand that our agricultural chemists should follow lines of a semi-technical, rather than of an investigational, character, in the sense that they have necessarily applied themselves to the problems of crop utilization, rather than to those having to do with the principles involved in their production. The principles of agricultural chemistry, which the early investigators established, and which were collated and formed into a science by the aid of the immortal Liebig, have served as the foundation for our work, and this basis has been sufficient to enable us to make great progress from the economic standpoint, so long as there were, in a sense, new worlds to conquer and new fields to cultivate, but do not fully serve when the rich stores of fertility in our fields have been, in part, exhausted.

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[1] An address delivered before the American Chemical Society at the Ithaca meeting.

In the next place, the conditions that existed here in the earlier history of our country, were not such as to demand on the part of the tiller of the soil, or farmer, a knowledge of those principles which would enable him to utilize to the best advantage soil fertility, and when the time came (as it has now for a large portion of our country), when knowledge of principles became a necessity, in order that farming on these areas might be made profitable, the first duty of the chemist was to rather demonstrate the usefulness of an application of the chemical knowledge already available. That is, the chemist became a teacher, rather than an investigator, and the results of his work have been altogether good. There is now a wide knowledge of underlying principles, among the more intelligent of our farmers, mainly, however, in respect to what we now know of the relationship between the soil, the plant and the animal. The farmer has been taught that the soil is potentially fertile, in proportion to the amount of nitrogen, phosphorus and potassium that it contains; that the removal of crops, resulting in the carrying away of these essential elements, will ultimately exhaust his soil to such an extent as to make their further growth unprofitable, without the addition of the other elements. He has, also, learned from the chemist that a judicious utilization of crops upon the farm, and a careful handling and use of waste products, will extend the period of profitable cropping. The chemists of the country have, also, rendered incalculable service in the study of those substances which carry these elements of fertility, and which are capable of serving as food for plants, and thus developing in a remarkable degree the farmer's ability to use them in the manufacture of crops, in the sense that they may be converted into products of high commercial value. The chemists have, also, promoted the intelligent purchase and use of commercial fertilizers, by the development and improvement of methods of chemical analysis, which enable them to accurately determine the various chemical forms. They have, also, by means of field experiments, demonstrated their comparative influence in meeting soil and crop requirements, and are thus able to give safe advice as to the value of the various supplies.

Still, with all this, and with the utilization of the products in the best manner, we are confronted with the fact that we have but little more definite knowledge of the soil and the principles involved in its treatment than we had sixty years ago. Fertility is not nitrogen, phosphorus and potassium alone, though the potential value of any field, or state or country, from the agricultural standpoint, is measured by these constituent elements in its soil, yet it has been demonstrated that soils which contain an abundance of these elements, and which are potentially capable of producing crops for centuries perhaps, are not capable of producing profitable crops without the addition of further amounts of these constituents. The chemical investigator is, therefore, obliged to take into consideration other facts than this. He must, if he would cover the whole field, know something of geology, of botany, of physics, of biology, of bacteriology and of the other natural sciences, because chemistry alone is not capable of fully compassing the problem, thus the opportunity for specializing in any branch has been very great, and it is because of the broadness of the subject, and the opportunity, as already pointed out, and the necessity, also, for giving immediate help from the knowledge that we have that has prevented in a degree a broad study of the fundamentals essential for enabling genuine progress to be made.

What are, therefore, some of the questions that now confront us, as chemists, and the solutions of which have so important a bearing upon the agricultural progress, and consequent true development and utilization of our resources? One of the first questions which, it seems to me, is important, is the question of the ultimate effect of the continued use of commercial fertilizers. The problem is before us now. Frequently, questions come which we can not answer. For example, the farmer who has used large quantities of commercial fertilizers for the growing of early potatoes, cabbage, celery, or any other crop of this class, states that his crops do not seem to respond to these applications in the same degree as formerly, and that increasing quantities are required to secure profitable results, notwithstanding calculations show a great accumulation of these elements in the soil. Furthermore, he has, also, learned that other crops in the rotation do not thrive as well as formerly. He can distinguish no marked difference in the character of his soil, but clover, alfalfa, beans or peas, do not grow as well as formerly. He is unable by a judicious seeding of crops, for supplying vegetable matter, to secure a normal and healthy growth. Hence, questions as to the cause of the trouble are asked of the chemist, but can not be answered fully by him. He is unable to point out the cause of the difficulty; he may suggest that the result is due to changes in the physical character of the soil, due to the undue removal of one or more element, not included in the commercial fertilizers applied; to the destruction of certain forms of bacteria, or to the development of plant poisons in the soil, but he has nothing definite to offer. Hence, it seems to me that this is an important problem for our chemists to solve, and which must be solved if we are to make progress, and to give to the farmer what he is justly entitled to, for have we not advised him, by our teachings, to follow the methods which he is now using, without warning as to the possible effect of his work? This condition of affairs applies more particularly to those sections of our country where the lands were not originally abundantly supplied with the essential elements. The areas now requiring large applications of commercial fertilizers are fortunately limited in this rich country of ours, yet they are so located in reference to markets as to make them increasingly valuable. In the richer sections, too, farmers are learning, by sad experience, that the productivity of their soils is not as great as formerly; they know now that their methods of farming have been wasteful, and that the available constituents have, in large part, been removed, yet they have been taught by the chemists that there exists in their soils such an abundance of the minerals as to make it possible to grow maximum crops for centuries, though they are unable, with the knowledge now available to them, to obtain as large crops as formerly, without the application of fertilizers. These areas are so large, that it is manifestly impossible, with the supplies of material in sight, to provide artificial fertilizers, in order to meet the situation; neither is such a practise warranted, with the vast quantities now present in the surface and subsoils. The chemist advises that it is probably a question of imperfect chemical, or physical, or bacteriological conditions of the soil, or of all these combined. The chemist should not deal in probabilities; he should be able to give positive advice. Hence, this is a problem for the chemist, and one worthy of his best thought—he must find out what the cause of apparent exhaustion is, and he should be able to show the farmer what his sources of loss are and be able to suggest a remedy. It has been shown by many experiments that in the ordinary and common methods of farm practise, there is a loss of the important element nitrogen, from the soil, greater than that accounted for by the removal of crops, and, furthermore, that the judicious application of commercial fertilizer or of yard manures does not result in proportionately increasing, or even maintaining the content of nitrogen in such soils. The chemist, with his present knowledge, advises that the loss may be due to either of three causes, or of one or more combined, viz., percolation into the drains, oxidation, or denitrification, but they are unable to suggest a method of practise which will remove the cause of loss. This is a problem of the first importance, the solution of which must rest with the chemist.

It is true that one phase of the nitrogen problem has been solved, but it has reference to the possible gain of nitrogen to soils, and thus in a sense compensates for the losses, though it makes the question of losses none the less important. I have reference, now, to discoveries that have been made, in regard to the symbiotic action of certain bacteria, which give to the leguminous plants their power of absorbing nitrogen from the air, and dispose of the question, in the sense that so long as the farmer judiciously uses any one of this class of crops in his rotation, it will be possible for him to, not only maintain, but to even increase the nitrogen content of his soils, and thus make the question of exhaustion from that standpoint one not to be feared. It seems to me, however, that we have but reached the threshold in these investigations, for while as a matter of fact such a practise will result in adding this important element to the soil, it does not dispose of the question of the full utilization of the nitrogen acquired. We have many instances of attempts made to improve soils, or to maintain their fertility by the introduction of leguminous crops, which have proved disastrous, rather than helpful, in promoting plant growth, or of permanently increasing fertility in this respect. Furthermore, we have no definite knowledge as yet, as to the conditions which are necessary in order that the plants shall appropriate nitrogen from the air, rather than from the soil, nor have we any definite information as to how large a proportion of the nitrogen so gathered is retained in the soil for the use of cereal and other crops which depend entirely upon soil sources for their nitrogen. I feel certain that no agricultural chemist of the present day would dare to risk his reputation on a positive statement, in reference to any one of these phases of the question. The nitrogen question in agriculture is far-reaching in its influence, affecting not only those who cultivate the soil, but those who depend upon its products for their sustenance and profit; it is a question which has occupied the student of chemistry from the earliest times, and the various theories advanced have caused no end of controversy among them, yet in many of its phases it is still a problem to be solved.

Another question, closely associated with this one of nitrogen, if not intimately connected therewith, is that of the importance of humus in relation to fertility. It has been recently stated by an eminent experiment station director that 'the mineral elements form but the skeleton of the soil, and without humus, which gives life and activity are practically useless as a medium for plant growth.' This statement is an attractive one, and may be in a broad sense correct, but, notwithstanding all of the investigations that have been made, I am of the opinion that much has yet to be learned as to the function of humus and the influence it exerts in the maintaining and improving of the fertility of our soils. We are unable from our present knowledge to state whether the effect is physical, chemical or biological, or whether it is a combined effect of each, or whether it is absolutely essential that the organic matter be present in large amounts, in order that the best results may be obtained. It is a problem well worthy of the attention of our agricultural chemists, and one which must be solved, if we are to give safe advice as to the cultivation of our soils.

Still another problem, which is agitating the minds of many far-seeing investigators, is the question of the supplies of artificial plant-food, aside from that involved in the question of nitrogen. As already pointed out, it has been clearly demonstrated that so far as the mineral elements are concerned, there is sufficient in the soils of this country to supply the needs of maximum crops for centuries, but this statement must be modified, so as to read 'sufficient to supply the needs of general crops, cereals and grasses, or any other crop which in its cultivation is allowed to develop under natural conditions,' but it does not apply to that class of crops, the need of which is increasing rapidly, that can not be grown to perfection in such quantities as to meet the demands of a modern civilization, without the stimulating effect of immediately available plant-food. I now refer to the large number of vegetable crops, fruits, berries, etc., which must be produced under semi-artificial conditions, in order that they may possess those characteristics of quality, and be provided at such times as the present demands require. There will, therefore, be a constantly increasing demand for plant-food, which can not be supplied by natural means, including the use of home-made manures.

The nitrogen question, as already pointed out, has received the attention of eminent investigators, and the problem has been solved in so far as the actual obtaining of free nitrogen from atmospheric sources, both by means of special classes of crops and by chemical combination. How soon the latter may be a practical source is still a question, but the progress thus far made indicates that the solution will be reached in the near future. There is, however, still a broad field for study, as to the source of supply of phosphates and of potash salts. We have in this country, and in Canada, enormous deposits of phosphate rock, already exploited; others will undoubtedly be found, so that the question is not one that requires such immediate attention. Nevertheless, with the great demands which are likely to be made, it is one well worthy of the study of our chemists. In the case of potash, we have no source of supply, at present, other than the Stassfurt mines of Germany, and the time must come, sooner or later, when these will not be able to meet the demand. Whether the potash stored in our granite hills are to supply these demands, or whether unknown deposits exist in our country, are questions that must occupy the minds of our agricultural chemists, and are problems which are of fundamental importance, because they have to do, not only with the production of crops, but with the future progress of humanity.

Still another question, or problem, which it seems to me the chemist should solve, is rather of economic importance than of pure science, since it has to do with the transfer of the plant-food elements from one place to another, and their loss, in so far as our own country is concerned. It is a problem which has been but lightly touched upon, though many have recognized its significance. We are exporting in whole grains, and in waste materials from our oil and starch factories, enormous quantities of human and animal foods, for which we receive a return only in proportion to nutritive values, whereas these products carry enormous quantities of constituents from our country. The problem here, as already stated, is not a problem so much of investigation as it is an exploitation of the facts, and the education of the people as to the possible ultimate effect. The agricultural chemist must stand as the conservator of the nation's wealth; he is the one whom others seek for definite information, and for guidance, and it is his business to so direct the attention of the people as to prevent an undue loss of our fertility elements.

There is no doubt but that by careful adjustments of trade conditions it will be possible to obtain quite as much money for our surplus products as is obtained at the present time, without having the practise result in so great an annual loss of our plant-food constituents. The problem is not an easy one to solve, though I am sure that with the earnest study and support of our agricultural chemists, it will be solved in a manner that will result in the best good to all. It is an important question, and one which I hope our chemists will regard as worthy of their study.

I am well aware that in this brief paper, which was purposely made general in its character, I have done little more than to point out some of the reasons why the conditions have not been favorable thus far for such work as seems now to be needed, and to suggest lines of investigation, without being specific as to the methods by which they should be carried out. Nevertheless, the few facts stated are patent to all who have given the subject thought, and are sufficient to indicate the importance of a broad and detailed study of the whole question of soil fertility. The field is now largely unoccupied, and there is a growing demand for broadly trained investigators, and there is no field of investigation more promising of fruitful results for the investigator and the country at large. Our professors of chemistry and our colleges and universities should cooperate in providing such opportunities for study as shall fit them to pursue this attractive and important line of investigation.

E. B. Voorhees.
New Jersey Agricultural
Experiment Station.

THE TEACHING OF SCIENCE IN COLLEGE.[1]

I wish to call attention to a situation which seems to me unnatural and unfortunate. It is unnecessary to present it in statistical form. No one will question that science in the colleges of this and other universities has not the importance and popularity that it should have, that this element of our modern education is by no means represented in the results of education in accordance with its importance.

It is not, however, to the failure to elect scientific courses as they are to-day or to enroll themselves for science degrees on the part of our students that I think especial attention should be directed. Nor do I think that we can explain this and other evidences of the deficiencies in this regard by the traditional prestige of the so-called humanities, or the prejudicing of the stu-

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[1] Address delivered before the Chicago Chapter Sigma Chi, March, 1906.